



US011808332B2

(12) **United States Patent**
Arce

(10) **Patent No.:** **US 11,808,332 B2**
(45) **Date of Patent:** **Nov. 7, 2023**

(54) **SELF-BINDING NON-JAMMING STOP
MODULE FOR ROTARY DRIVE ACTUATOR**

F16H 35/00 (2006.01)
B64C 13/34 (2006.01)

(71) Applicant: **MOOG INC.**, Elma, NY (US)

(52) **U.S. Cl.**
CPC *F16H 35/00* (2013.01); *B64C 13/34*
(2013.01); *F16D 55/02* (2013.01); *F16D*
59/00 (2013.01); *F16D 2121/14* (2013.01);
F16D 2125/40 (2013.01); *F16D 2125/50*
(2013.01); *F16H 2035/006* (2013.01)

(72) Inventor: **Arturo M. Arce**, Huntington Beach,
CA (US)

(73) Assignee: **Moog Inc.**, Elma, NY (US)

(58) **Field of Classification Search**
CPC F16H 1/46; F16H 2035/005; F16H
2035/006; F16H 25/2021; F16H 25/2018;
F16D 55/02; F16D 59/00; F16D 2121/14;
F16D 2125/40; F16D 2125/50
See application file for complete search history.

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 342 days.

(21) Appl. No.: **17/423,384**

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(22) PCT Filed: **Feb. 24, 2020**

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(86) PCT No.: **PCT/US2020/019407**

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(2) Date: **Jul. 15, 2021**

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(87) PCT Pub. No.: **WO2020/176375**

PCT Pub. Date: **Sep. 3, 2020**

(65) **Prior Publication Data**

US 2022/0128137 A1 Apr. 28, 2022

Related U.S. Application Data

(60) Provisional application No. 62/810,130, filed on Feb.
25, 2019.

(Continued)

Primary Examiner — Huan Le

Assistant Examiner — Aimee Tran Nguyen

(74) *Attorney, Agent, or Firm* — Hodgson Russ LLP

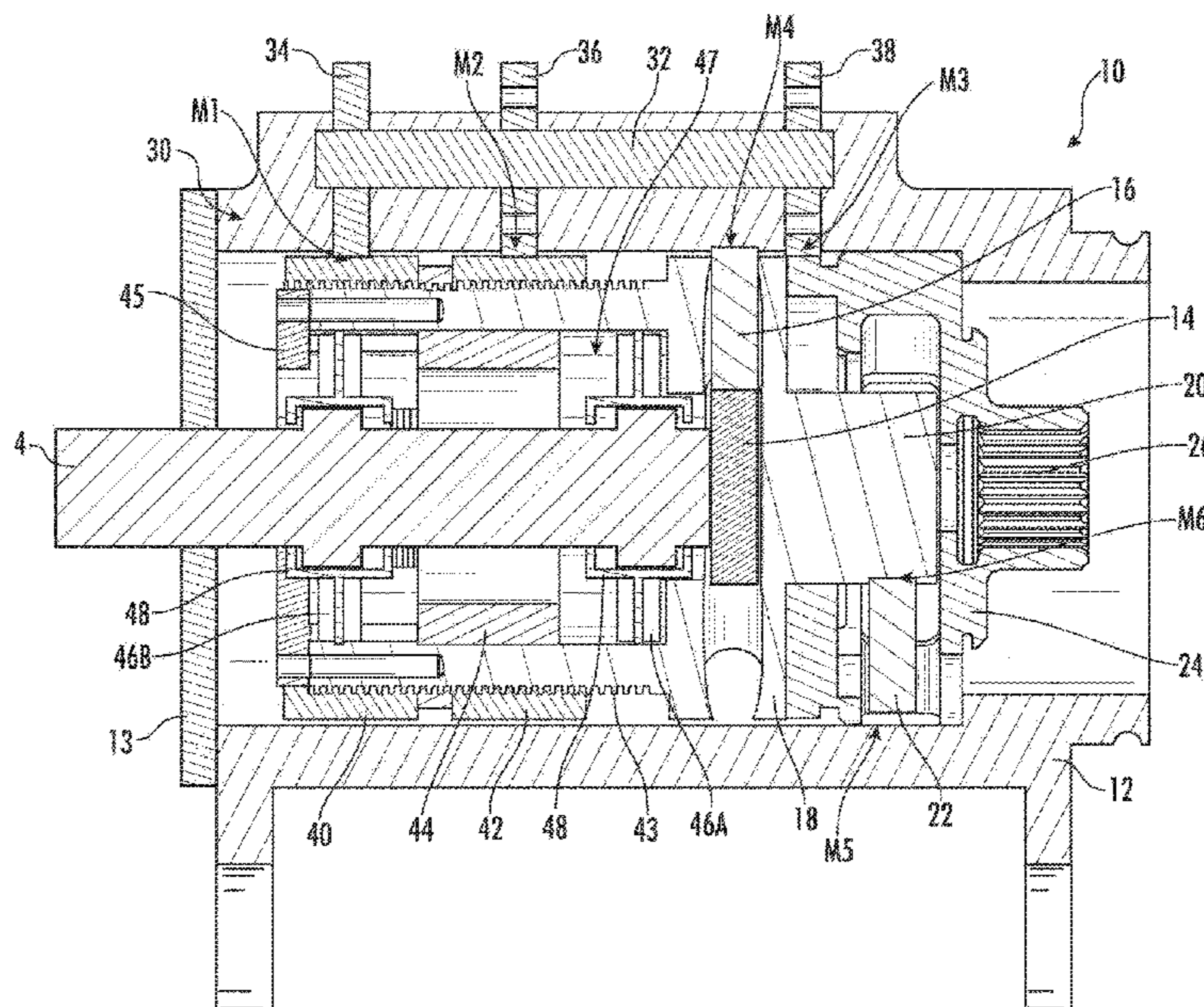
(51) **Int. Cl.**

F16D 55/02 (2006.01)
F16D 59/00 (2006.01)
F16D 121/14 (2012.01)
F16D 125/40 (2012.01)
F16D 125/50 (2012.01)

(57) **ABSTRACT**

A rotary actuator has a stop module configured to mechani-
cally link two gear stages travelling at different rotational
speeds when an end-of-stroke travel limit is reached, thereby
causing the rotary actuator to bind because relative motion
between the gear stages is impeded.

11 Claims, 5 Drawing Sheets



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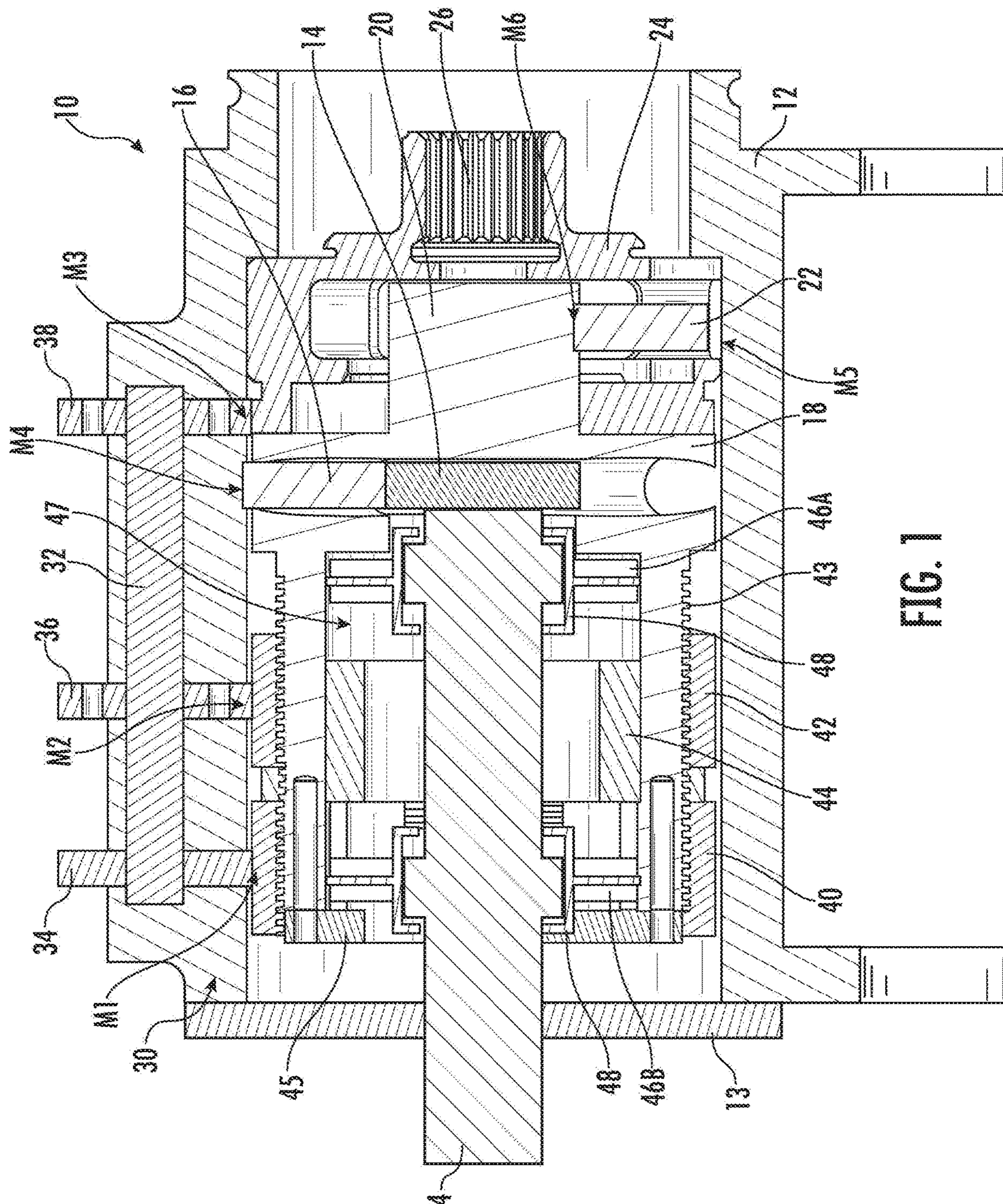


FIG. 1

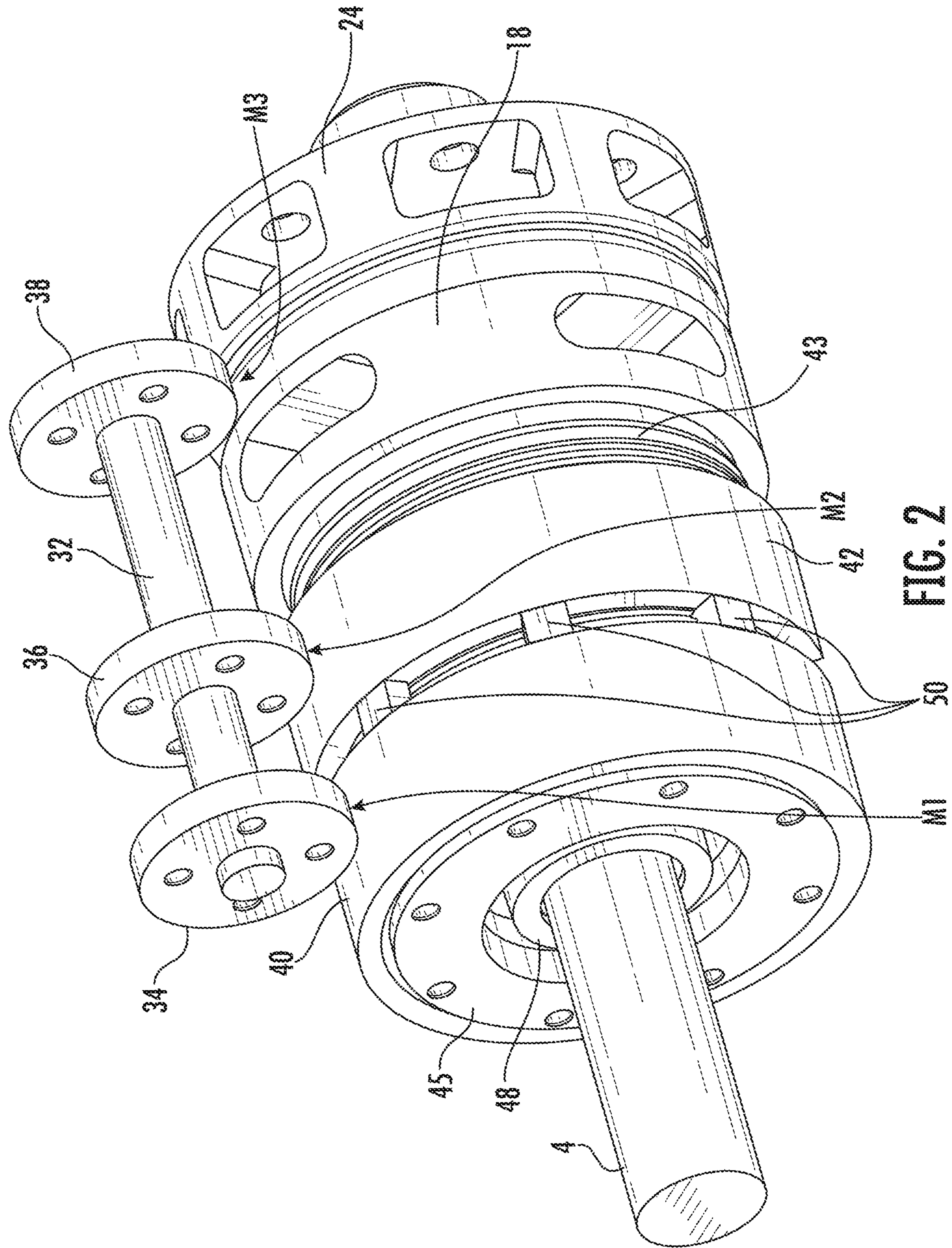


FIG. 2

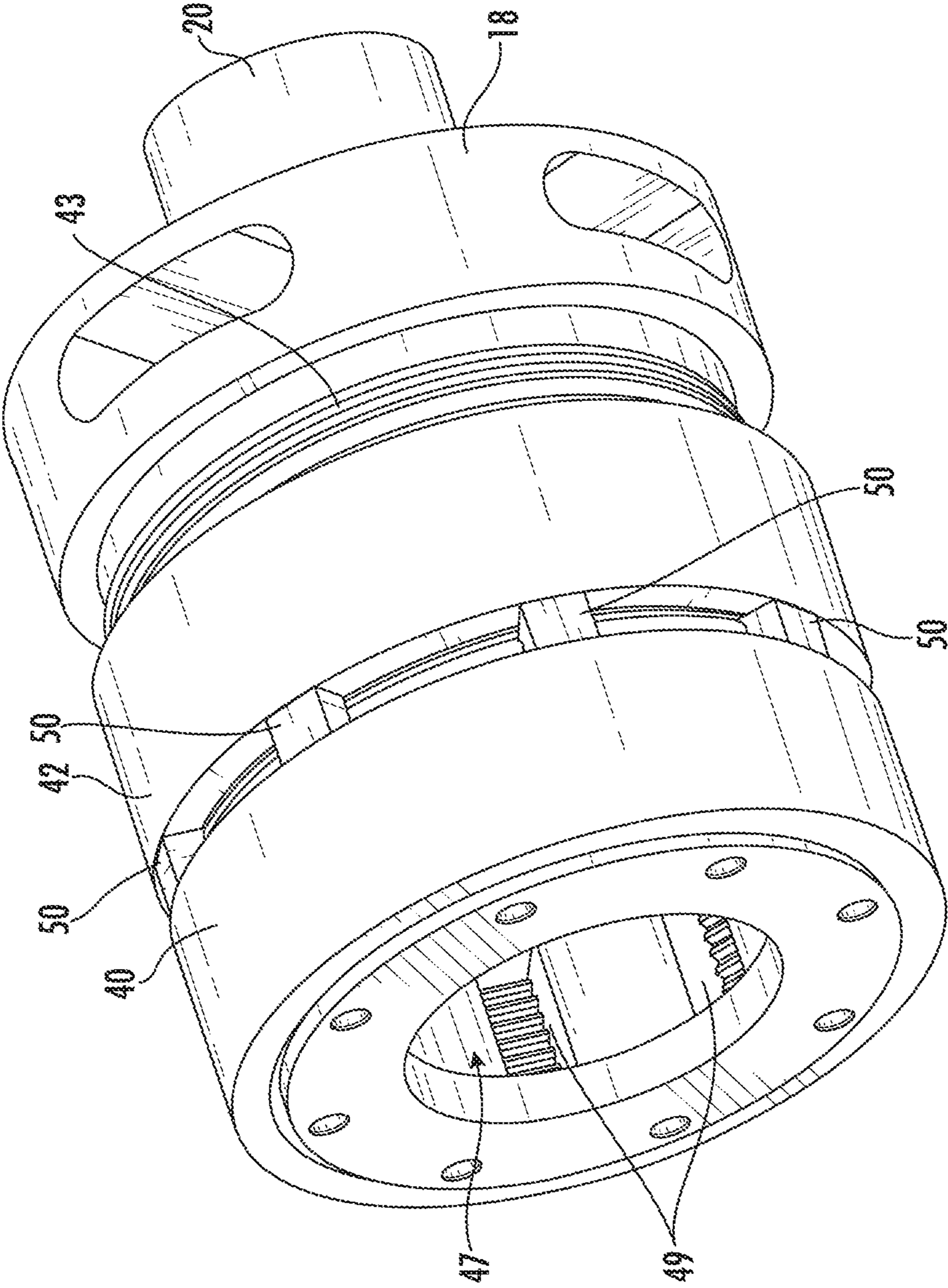


FIG. 3

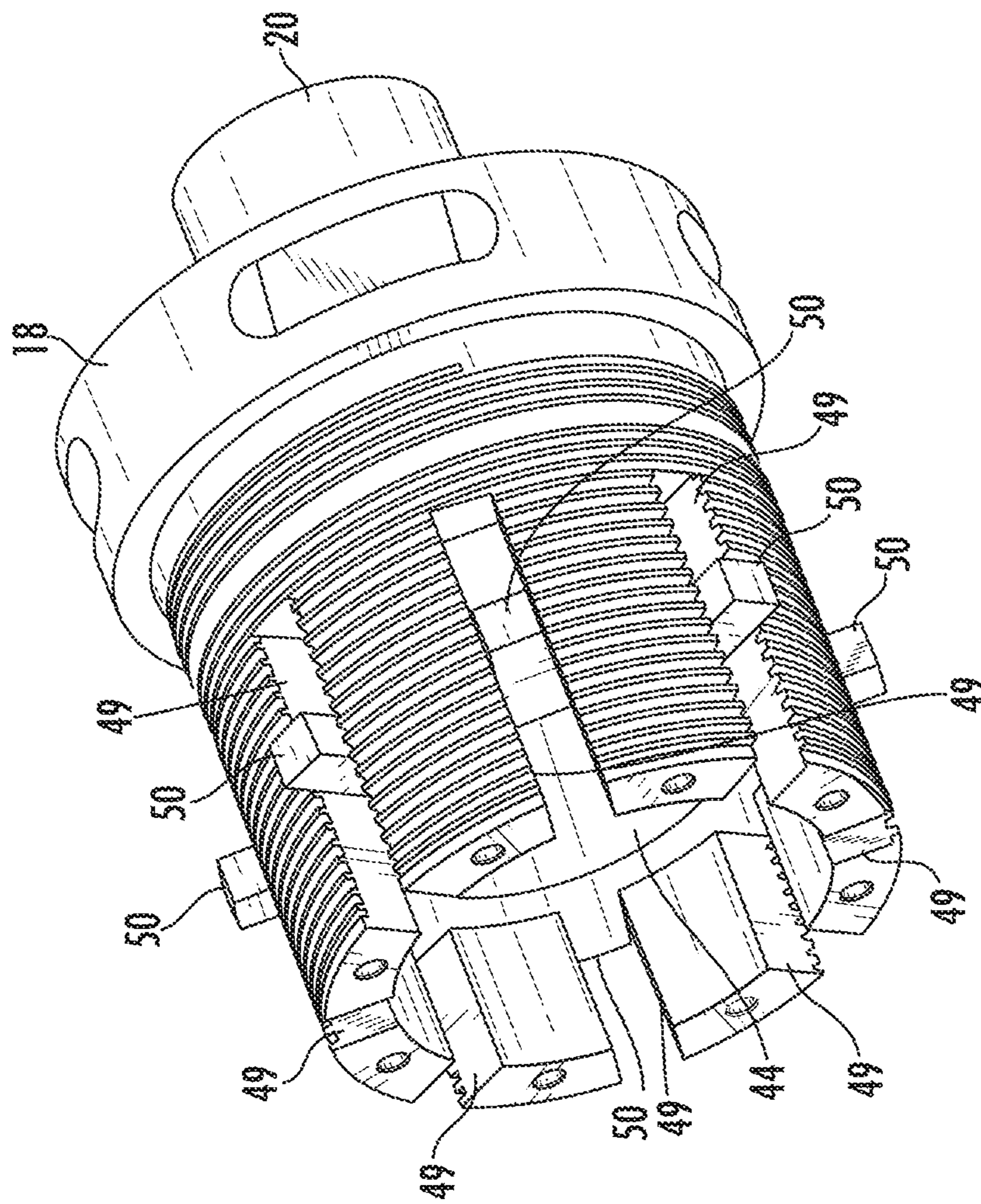


FIG. 4

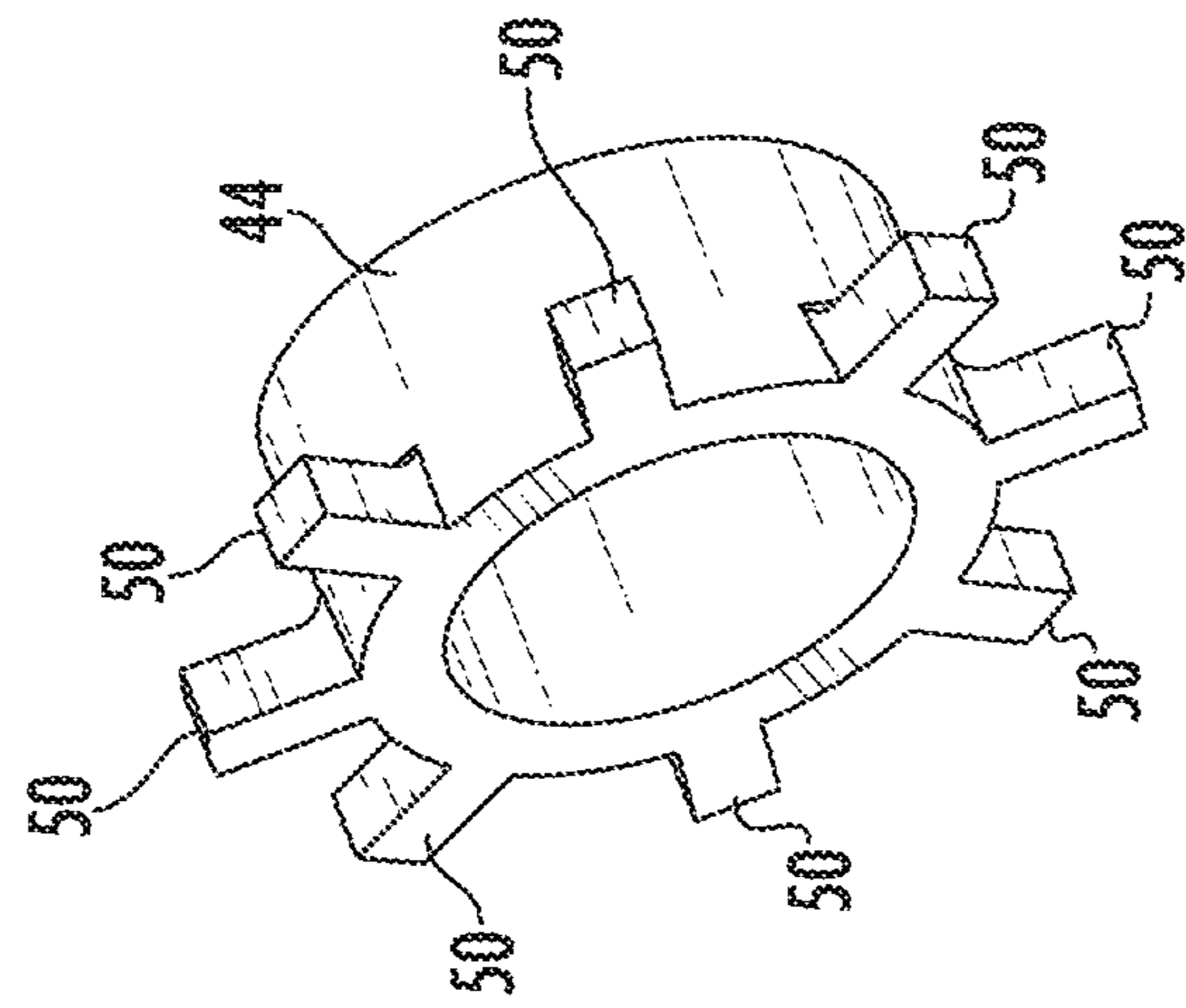


FIG. 5

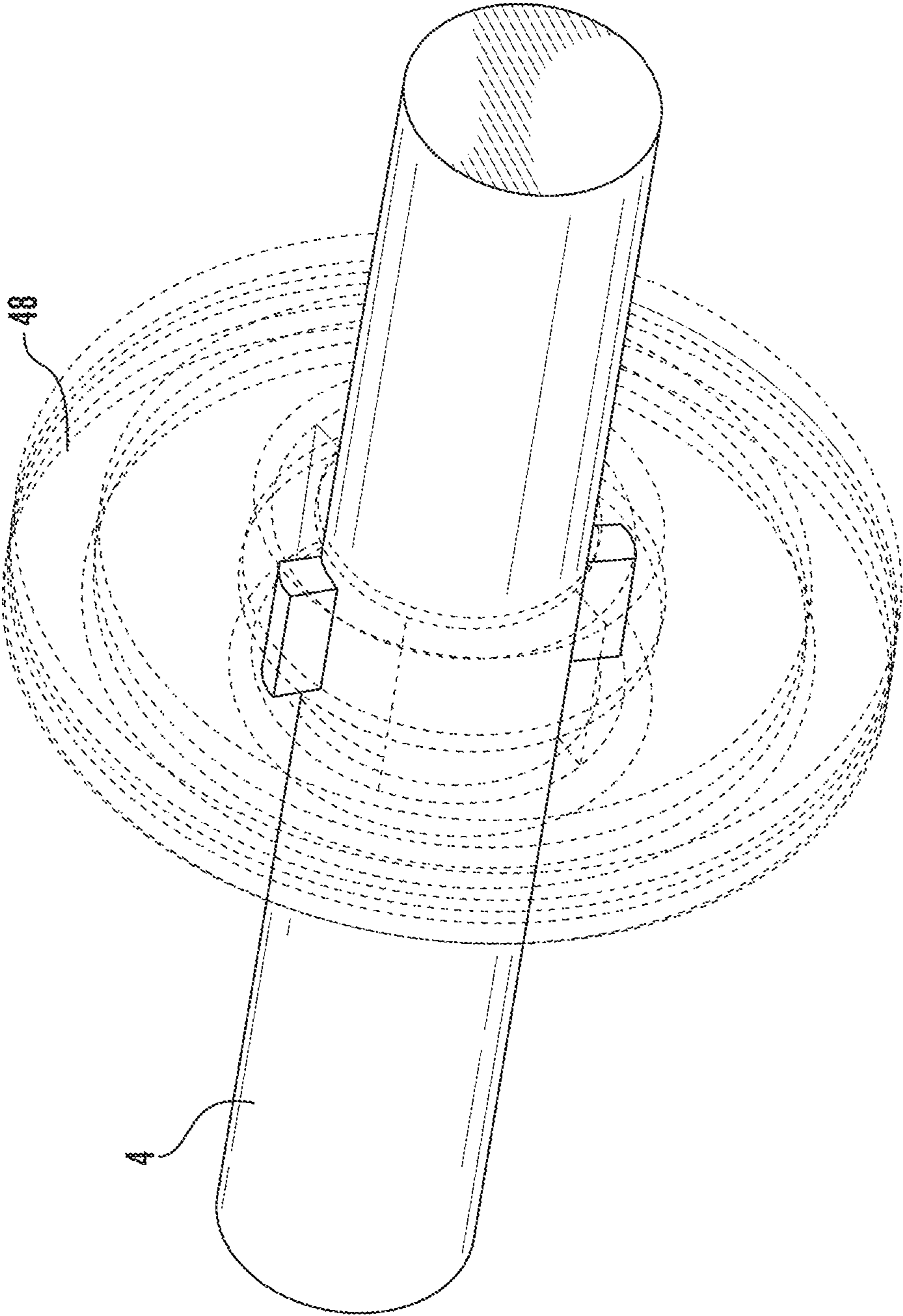


FIG. 6

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SELF-BINDING NON-JAMMING STOP MODULE FOR ROTARY DRIVE ACTUATOR

FIELD OF THE DISCLOSURE

The present disclosure relates to a travel-limiting stop module for providing a mechanical stop at either end or both ends of a predefined stroke of a rotary drive actuator. For example, the present disclosure may be applied, but is not limited, to geared rotary actuators (GRAs) used in actuation systems for aircraft control surfaces.

BACKGROUND OF THE DISCLOSURE

End-of-stroke stopping mechanisms, also referred to as stop modules, dissipate excess rotational kinetic energy of a rotational drive system to stop rotation when a travel limit in a given direction of travel is reached. In some applications, the excess rotational kinetic energy may be significant, and it must be dissipated very quickly. For example, a GRA in an actuation system for displacing an aircraft flight control surface may be driven by a hydraulic motor at very high revolutions per minute, and rotation must be safely stopped within a very short time span. It is desirable to provide a stopping mechanism which resists jamming when a hard stop is reached at a travel limit position, and is resettable by reverse rotation of an input drive shaft. Furthermore, it is advantageous to minimize the weight and size of the stopping mechanism, especially for aircraft applications.

In a GRA having a multistage planetary gear system, one set of gears will travel at a different rotational speed than another set of gears. The inventor has realized that the difference in rotational speeds may be exploited to provide a non-jamming stopping mechanism which is mechanically simple, lightweight, and small, and which resets on reverse rotation.

SUMMARY OF THE DISCLOSURE

A rotary actuator has a stop module configured to mechanically link two gear stages travelling at different rotational speeds when an end-of-stroke travel limit is reached, thereby causing the rotary actuator to bind because relative motion between the gear stages is impeded. The rotary actuator may comprise an input shaft rotatably driven by an input torque, a first gear stage having a first stage carrier driven to rotate by rotation of the input shaft, and a second gear stage having a second stage carrier driven to rotate by rotation of the first stage carrier. The first stage carrier may include a threaded portion, and the second stage carrier may include gear teeth.

The stop module may include a first spur gear nut and a second spur gear nut threadably mated with the threaded portion of the first stage carrier, a brake plate arranged for travel with the first and second nuts along an axis of the threaded portion of the first stage carrier, and first and second brake disks coupled to the input shaft to define opposite end-of-stroke travel limits. A transmission assembly may be configured to transmit rotational motion of the second stage carrier to the first and second nuts to cause the first and second nuts to travel axially along the axis of the threaded portion of the first stage carrier, wherein the brake plate is caused to engage the first brake disk at a first end-of-stroke travel limit of the rotary actuator to stop rotation of the input shaft in a first rotational direction, and the brake plate is caused to engage the second brake disk at

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a second end-of-stroke travel limit of the rotary actuator to stop rotation of the input shaft in a second rotational direction.

BRIEF DESCRIPTION OF THE DRAWINGS

The nature and mode of operation of the present invention will now be more fully described in the following detailed description taken with the accompanying drawing figures, in which:

FIG. 1 is a cross-sectional view of GRA configured with a stop module of the present disclosure, wherein the GRA is coupled to an input drive shaft;

FIG. 2 is perspective view of the GRA and input drive shaft of FIG. 1, wherein the GRA is shown without its housing for sake of clarity;

FIG. 3 is a perspective view showing a subassembly of the GRA including a pair of spur gear nuts engaging with a translating brake plate and a first stage carrier;

FIG. 4 is a perspective view of the translating brake plate mating with the first stage carrier;

FIG. 5 is a perspective view of the translating brake plate in isolation; and

FIG. 6 is a perspective view, partially transparent, showing an anti-jamming coupling of the stop module mated with the input drive shaft.

DETAILED DESCRIPTION OF THE DISCLOSURE

FIG. 1 shows a GRA 10 connected to an input shaft 4 driven to rotate by a motor (not shown). The motor may be any type, including a hydraulic motor, an electric motor, a pneumatic motor, or an internal combustion engine. GRA 10 is configured to include a stop module 30 described in detail below.

Referring also now to FIGS. 2-6, GRA 10 may comprise a first planetary gear stage including a sun gear 14 arranged at an end of input shaft 4. Sun gear 14 has external gear teeth and may mesh with a first set of planet gears 16, which in turn may mesh with internal gear teeth fixed in housing 12 such that housing 12 acts as a ring gear for the first planetary gear stage. The first planetary gear stage may further include a first stage carrier 18 coupled to planet gears 16, whereby the first stage carrier 18 is driven to rotate about the axis of input shaft 4 upon rotation of the input shaft. An end portion of first stage carrier 18 may have external gear teeth to act as a sun gear 20 of a second planetary gear stage of GRA 10. The second planetary gear stage may further include a second set of planet gears 22 meshed with sun gear 20 and with internal gear teeth fixed in housing 12 forming a ring gear for the second planetary gear stage. The second planetary gear stage may also include a second stage carrier 24 coupled to planet gears 22, whereby the second stage carrier 24 is driven to rotate about the axis of input shaft 4 upon rotation of input shaft 4 and first stage carrier 18. The first and second gear stages of GRA 10 may be configured such that first stage carrier 18 rotates at a higher speed (i.e. higher rpm) than second stage carrier 24 for a given rotational speed of input shaft 4. Second stage carrier 24 may include an output spline 26 for connection to a load (not shown). An end cover 13 may be fastened to housing 12. The figures are simplified by omitting detailed depiction of gear teeth.

Stop module 30 may comprise a brake transfer shaft 32 on which a first spur gear 34, a second spur gear 36, and a third spur gear 38 are mounted for rotation with the brake transfer shaft 32. First spur gear 34 may be meshed at M1 with a first

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spur gear nut **40** having external gear teeth and internal screw threads. Likewise, second spur gear **36** may be meshed at **M2** with a second spur gear nut **42** having external gear teeth and internal screw threads, for example acme screw threads. Spur gear nuts **40** and **42** may be threadably mated on a threaded portion **43** of first stage carrier **18** such that relative rotation between spur gear nuts **40** and **42** on the one hand and first stage carrier **18** on the other will cause spur gear nuts **40** and **42** to travel in an axial direction along threaded portion **43** of first stage carrier **18**. As will be understood, the direction of travel of spur gear nuts **40** and **42** is dependent upon the direction of rotation of input shaft **4**. Threaded portion **43** of first stage carrier **18** may have an externally threaded cylindrical wall surrounding an axial travel passage **47**.

A translating brake plate **44** may be captured between spur gear nuts **40** and **42**. In the illustrated arrangement, brake plate **44** is received within travel passage **47** of threaded portion **43**, and may include a plurality of radial spokes **50** each received within a corresponding axially extending slot **49** through the cylindrical wall of threaded portion **43**. A radially outer end of each spoke **50** may extend into a gap between spur gear nuts **40** and **42**, whereby axially directed motion of the spur gear nuts **40** and **42** is transmitted to translating brake plate **44** by engagement of the pushing nut with the radially outer ends of spokes **50**. As a result, translating brake plate **44** travels axially along threaded portion **43** with spur gear nuts **40** and **42**. An end plate **45** may be fastened to an end of threaded portion **43** of first stage carrier **18**.

A first brake disk **46A** and a second brake disk **46B** may be arranged at opposite ends within the cylindrical wall of threaded portion **43**. An anti-jamming coupling **48** may be provided for each brake disk **46A**, **46B**.

In the illustrated embodiment, transfer shaft **32**, first spur gear **34**, second spur gear **36**, and third spur gear **38** provide a transmission assembly configured to transmit rotational motion of second stage carrier **24** to first spur gear nut **40** and second spur gear nut **42** to cause the first and second nuts **40**, **42** and brake plate **44** to travel in opposite directions along the axis of threaded portion **43** of the first stage carrier **18**. In this context, third gear **38** may be thought of as an input gear of the transmission assembly, while first gear **34** and second gear **36** may be thought of as first and second output gears of the transmission assembly, respectively. The direction of axial travel of brake plate **44** depends upon the rotation direction of input shaft **4**. As may be understood, the transmission assembly is subject to modification and may take on a variety of forms.

Operation of stop module **30** may be described as follows. A clockwise input torque/speed is provided to the system via the input shaft **4** rotating sun gear **14** of the first planetary gear stage. Input shaft **4** carries with it the two brake disks **46A**, **46B** attached through the respective anti-jamming couplings **48**. The clockwise rotational output of the first stage planetary gear system is realized by first stage carrier **18**, thereby driving sun gear **20** of the second stage planetary gear system. The clockwise output of the second stage planetary gear system is realized by second stage carrier **24**. Second stage carrier **24** outputs torque/speed to drive a load or another set of gears, and simultaneously drives third spur gear **38**. Third spur gear **38** transfers torque/speed through brake transfer shaft **32** to drive first spur gear **34** and second spur gear **36**. First and second spur gears **34**, **36** respectively drive first and second spur gear nuts **40**, **42**. As the first and second spur gear nuts **40**, **42** rotate about the mating threaded portion **43** of first stage carrier **18**, they translate

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along the axis of input shaft **4**. The linear motion pushes on translating brake plate **44** until translating brake plate **44** squeezes on first brake disk **46A**. Squeezing on first brake disk **46A** causes input shaft **4** to decelerate until the entire system stops. This is the maximum travel that can be achieved in the clockwise direction. Any further torque provided through input shaft **4** in the clockwise direction will be counteracted by this jamming effect, thus mating the system stationary.

If counter-clockwise rotation of input shaft **4** is then commanded, the anti-jamming coupling **48** allows the input shaft **4** to rotate in the counter-clockwise direction, thereby reversing the series of operations described above and freeing first brake disk **46A**. Continuing to provide rotation in the counter-clockwise direction will cause the process to continue in the opposite direction, making translating brake plate **44** move towards second brake disk **46B** until it squeezes on second brake disk **46B** impeding further motion.

The illustrated embodiment is bidirectional, however a unidirectional embodiment having only one nut for pushing brake plate **44** in one axial direction toward only one brake disk is within the scope of the disclosure.

While the present disclosure describes exemplary embodiments, the detailed description is not intended to limit the scope of the invention to the particular forms set forth. The invention is intended to cover such alternatives, modifications and equivalents of the described embodiments as may be apparent to one of ordinary skill in the art.

What is claimed is:

1. A rotary actuator comprising:
 - an input shaft rotatably driven by an input torque;
 - a first gear stage having a first stage carrier driven to rotate by rotation of the input shaft, the first stage carrier including a threaded portion;
 - a second gear stage having a second stage carrier driven to rotate by rotation of the first stage carrier, wherein the second stage carrier includes gear teeth;
 - a first nut threadably mated with the threaded portion of the first stage carrier, wherein the first nut includes gear teeth;
 - a brake plate arranged for travel with the first nut along an axis of the threaded portion of the first stage carrier;
 - a first brake disk coupled to the input shaft; and
 - a transmission assembly configured to transmit rotational motion of the second stage carrier to the first nut to cause the first nut and the brake plate to travel in a first axial direction along the axis of the threaded portion of the first stage carrier;
 - wherein the brake plate engages the first brake disk at a first end-of-stroke travel limit of the rotary actuator to stop rotation of the input shaft.
2. The rotary actuator according to claim 1, further comprising:
 - a second nut threadably mated with the threaded portion of the first stage carrier, wherein the second nut includes gear teeth;
 - a second brake disk coupled to the input shaft;
 - wherein the brake plate is arranged for travel with the second nut along the axis of the threaded portion of the first stage carrier;
 - wherein the transmission assembly is further configured to transmit rotational motion of the second stage carrier to the second nut to cause the second nut and the brake plate to travel in a second axial direction along the axis of the threaded portion of the first stage carrier opposite to the first axial direction;

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wherein the brake plate engages the second brake disk at a second end-of-stroke travel limit of the rotary actuator to stop rotation of the input shaft.

3. The rotary actuator according to claim 2, wherein the brake plate is arranged between the first nut and the second nut.

4. The rotary actuator according to claim 2, wherein the threaded portion of the first stage carrier includes a cylindrical wall surrounding an axial travel passage, the cylindrical wall having a plurality of axially extending slots therethrough, and the brake plate is received within the travel passage and includes a plurality of radial spokes extending through the plurality of slots for engagement with the first nut and the second nut.

5. The rotary actuator according to claim 2, wherein the first nut is a first spur gear nut having gear teeth, the second nut is a second spur gear nut having gear teeth, and the transmission assembly includes a transfer shaft having an input gear meshed with the gear teeth of the second stage carrier, a first output gear meshed with the gear teeth of the first spur gear nut, and a second output gear meshed with the gear teeth of the second spur gear nut.

6. The rotary actuator according to claim 2, further comprising a first anti-jamming coupling for coupling the first brake disk to the input shaft, and a second anti-jamming coupling for coupling the second brake disk to the input shaft.

7. The rotary actuator according to claim 1, wherein the threaded portion of the first stage carrier includes a cylindrical wall surrounding an axial travel passage, the cylindrical wall having a plurality of axially extending slots

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therethrough, and the brake plate is received within the travel passage and includes a plurality of radial spokes extending through the plurality of slots for engagement with the first nut.

8. The rotary actuator according to claim 1, wherein the first nut is a first spur gear nut having gear teeth, and the transmission assembly includes a transfer shaft having an input gear meshed with the gear teeth of the second stage carrier and a first output gear meshed with the gear teeth of the first spur gear nut.

9. The rotary actuator according to claim 1, further comprising an anti jamming coupling for coupling the first brake disk to the input shaft.

10. The rotary actuator according to claim 1, wherein the first gear stage is a planetary gear stage having a first sun gear coupled to the input shaft for rotation with the input shaft, a first ring gear surrounding the first sun gear, a first set of planetary gears meshed with the first sun gear and the first ring gear, wherein the first stage carrier rotates with the first set of planetary gears about a rotational axis of the input shaft.

11. The rotary actuator according to claim 10, wherein the second gear stage is a planetary gear stage having a second sun gear coupled to the first stage carrier for rotation with the first stage carrier, a second ring gear surrounding the second sun gear, a second set of planetary gears meshed with the second sun gear and the second ring gear, wherein the second stage carrier rotates with the second set of planetary gears about a rotational axis of the input shaft.

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